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BEEF CATTLE RESEARCH
AT THE
U. S. MEAT ANIMAL RESEARCH CENTER¹

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¹North Central Region, Agricultural Research Service, U. S. Department of Agriculture.

U. S. MEAT ANIMAL RESEARCH CENTER¹

Clay Center, Nebraska

BEEF CATTLE RESEARCH PROGRAM

INTRODUCTION

The primary objective of the beef cattle research program at the U.S. Meat Animal Research Center is to develop new technology that can be used by producers to increase production efficiency and improve quality or desirability of product. Technology provided by this program is expected to assist producers in making better managerial decisions for achieving the goal of increasing the conversion rate of feed and other resources, which they either own or over which they can acquire control, into edible beef of appropriate palatability to meet specific consumer requirements. The research is organized on a multidiscipline, integrated basis with comprehensive efforts involving the areas of genetics and breeding, nutrition, reproduction, carcass and meats, livestock engineering, herd health and disease management, and management systems.

A basic objective in planning beef cattle research at the U.S. Meat Animal Research Center is to develop programs that will yield technology needed for the optimum synchronization of production resources into management systems that will maximize the conversion rate of these resources. A general understanding of the capability of resources that either are available or will be available to meet different types of production requirements is fundamental to effective research planning. Also, it is essential to know market requirements for the product. For example, we know that increased milk level and increased cow size result in increased feed requirements in order to achieve a high level of reproduction. The potential value of the additional performance capability in relation to feed availability and other costs determines the economic feasibility of pursuing higher production capability. Animals with extremely high growth potential and a slower rate of maturity may require a different type of feed resource to reach market condition at optimum slaughter weights than is economically feasible to provide with some feed resources. Restricted feed environments may actually favor animals with a lower performance potential for certain traits. Thus, the breeding and genetics, nutrition, carcass and meats, reproduction, and management systems research components of a comprehensive program must be considered simultaneously in planning, implementing and executing research focusing on production resource capability and market requirements.

¹ North Central Region, Agricultural Research Service, U.S. Department of Agriculture

A high percentage of the efforts in this comprehensive research program is organized on a multidiscipline, integrated basis. It is anticipated that the beef cattle research program will be critically reviewed and updated on an annual basis to reflect inputs by the Advisory Committee, the Technical Collaborators Group, the Research Committee of the American National Cattlemen's Association, joint Agricultural Research Service/State Agricultural Experiment Station regional and national level research planning efforts and from other appropriate interests of the livestock industry, Agricultural Research Service and State Agricultural Experiment Stations.

The U. S. Meat Animal Research Center now has collaborative research efforts on beef cattle with several State Agricultural Experiment Stations in addition to the Nebraska Agricultural Experiment Station. Also, the U. S. Meat Animal Research Center is collaborating with the Research Branch, Canada Department of Agriculture on the Germ Plasm Evaluation Program. It is expected that collaborative programs with State Agricultural Experiment Stations will continue to expand as the program develops.

Although a high percentage of the research program is conducted on a multidiscipline basis, for simplicity, this report is organized on a discipline basis. The areas of research and specific projects are classified under the disciplinary heading involving the Research Unit which is expected to provide the primary leadership in planning and conducting the program. However, it is recognized that there will be some exceptions to this to reflect changes in research program emphasis, etc., as specific programs evolve.

I. GENETICS AND BREEDING

A. General Objective. Develop procedures for more effective utilization of additive and nonadditive genetic variation for increasing biological and economic efficiency. A high percentage of the efforts will relate to developing the understanding necessary for synchronizing germ plasm resources with the other resources available for beef production and to the requirements of the market.

B. Specific Programs.

1. Research Area:

Selection for Weaning Weight, Yearling Weight and Muscling in Beef Cattle

a. Objectives:

- (1) Determine the effects of selection for economic traits of beef cattle.
- (2) Determine the heritabilities of and the genetic correlations among economic traits of beef cattle.

b. Procedure and Accomplishments:

(1) Procedure. This project relates primarily to the direct interests of the seedstock segment of the industry in regard to maximizing the rate of genetic improvement for the traits of economic value. The commercial segment looks to the seedstock segment for continued genetic improvement, regardless of whether the commercial program is one of straightbreeding or crossbreeding. Genetic worth of commercial herds is, over time, largely a function of genetic worth of bulls made available for use by the seedstock segment.

Four 150-cow-6-sire lines of Hereford cattle are selected on the basis of: (1) weaning weight, (2) yearling weight, (3) an index of yearling weight and muscling score, and (4) a control population that is maintained without deliberate selection. Selection response is estimated from cumulative deviation from control population relative to cumulative selection differentials. Also, the repeated use of three sires over 2 years in each line permits estimates of genetic change by intrayear comparison of progeny from sires of different birth years.

(2) Accomplishments. Results from selection applied and response for the 2,956 calves born from 1960 to 1970 in the three selection lines show that rate of improvement by selection was about 2.5 to 3.5% per generation or 0.5 to 0.75% per year for primary selection traits. This rate of improvement, though low, can add to the 4 to 6% increase in growth rate expected from crossbreeding. Correlated response among performance traits suggests a wide variety of selection patterns will lead to improvement in all traits. However, maximum improvement in particular traits could best be achieved by single trait selection or use of an optimum index.

Response per unit of selection (heritability) was 0.47 for birth weight, 0.10 for weaning gain, 0.12 for weaning weight, 0.37 for postweaning gain, 0.48 for yearling weight, and 0.31 for muscling score. Birth weight appeared highly correlated genetically with all performance traits. Expected increase in birth weight could be reduced 30% if all emphasis on growth was directed to postnatal growth rate rather than weaning or yearling weight. Results of the analysis suggests selection for postweaning gain or yearling weight may increase weaning gain or weight more than direct selection for weaning traits.

Average sire selection differentials (expressed in standard deviation units) in the Weaning Weight, Yearling Weight and Yearling Weight-Muscling Score lines were, respectively: weaning weight 1.51, 1.18, 0.86; yearling weight 1.42, 1.79, 1.22; muscling score 0.51, 1.11, 2.13. Comparable dam selection differentials were: weaning weight 0.40, 0.20, 0.31; yearling weight 0.35, 0.26, 0.42; muscling score 0.02, 0.02, 0.02. Selection differentials in males represented 80 to 90% of the actual midparent selection differentials. A comparison of selected parents with maximum potential selection differentials indicated 77 to 97% of selection opportunity in the primary criteria was used in male selection and 50 to 71% in selecting females.

c. Current Status:

- (1) A control line, established from foundation cows bred with semen from foundation sires, was added to the study in 1971 to provide an additional direct measure of selection response.
- (2) Presently there are approximately 600 cows, 2 or more years of age and 200 yearling heifers in the three selection lines and the control population.

d. Research Plans:

- (1) Continue project for another 10 to 15 years.
- (2) Complete analysis of individual feeding and carcass data to obtain measure of correlated response in these traits.
- (3) Determine response from selection over several generations in selected lines relative to the control line.

2. Research Area:

Evaluation of Heterosis Obtained from Crosses of Inbred Lines of Hereford Cattle

a. Objectives:

- (1) To determine the level of heterosis obtained in crosses of inbred lines relative to non-inbred cattle of the same ancestry.

b. Progress:

- (1) Postweaning growth, reproduction and maternal performance of Hereford females from four inbred lines (avg. inbreeding about 30%), a control line (avg. inbreeding 3%), line crosses and topcrosses (inbred sire x control dam) are being evaluated when mated to the same bulls of a different breed. Line crosses are being compared to inbreds to evaluated effects of heterosis and line crosses are being compared to control topcross females to evaluate whether heterosis any more than recovers the decline in reproduction and maternal performance that resulted from accumulated inbreeding in inbred lines.
- (2) Indications, to date, are that reproductive performance of line crosses is greater than inbred females, but line crosses have not exceeded control line or topcross females in reproductive performance.
- (3) This project is conducted cooperatively with the South Dakota Agricultural Experiment Station.

c. Current Status:

- (1) A total of 250 females have been introduced from the South Dakota Agricultural Experiment Station into this program.

d. Research Plans:

- (1) Continue mating of females to sires of a different breed to accomplish the objective of the project.
- (2) Project will be completed in 1977.

3. Research Area:

Effects of Heterosis on Productive Efficiency and Carcass Merit in Beef Cattle

a. Objectives:

- (1) Evaluate the effects of heterosis in crosses among the Angus, Hereford and Shorthorn breeds.
- (2) Determine the importance of epistatic recombination effects in advanced generations of two-breed and three-breed rotations involving Herefords, Angus and Shorthorns.

b. Procedure and Accomplishments:

(1) The comprehensive heterosis study involving the Hereford-Angus and Shorthorn breeds was initiated at the Fort Robinson Beef Cattle Research Station and has been conducted in three phases. Phase I dealt with estimation of individual heterosis expressed by the F_1 calf, phase II with maternal heterosis expressed by the F_1 cow, and phase III (now completed) has evaluated the level of heterosis restored from one generation to the next by two- and three-breed rotational systems of crossbreeding. Results from phase I and phase II of this experiment show that production per cow in the breeding herd can be increased 23% by combined effects of heterosis on survival and growth of crossbred calves and by maternal heterosis associated with a higher level of reproduction and greater and more persistent milk production of crossbred cows relative to straightbreds. More than half of this advantage is due to use of crossbred cows.

Individual heterosis (phase I). The three straightbreds and reciprocal crosses among Herefords, Angus and Shorthorns were produced in four calf crops and the data included 751 calves. A series of economically important traits were studied.

There was no difference between crossbred and straightbred calves for percent calf crop born, but early postnatal survival was significantly greater in crossbreds. Crossbred calves were 4.6% heavier at weaning (7 months of age) than straightbreds. The combined advantages in survival and growth rate accounted for an 8.5% advantage in pounds-of-calf-weaned-per-cow-exposed in favor of crossbred calves over straightbred calves. Age at puberty (first estrus) was 35 to 40 days younger for crossbred than for straightbred heifers.

A second study involving straightbreds and reciprocal crosses among Hereford and Angus evaluated effects of heterosis on survival and growth of the F_1 offspring and effects of sex-nutrition level interaction on postweaning growth and carcass characteristics. This study, completed in 1973, demonstrated that the effects

of heterosis on growth is larger in accelerated management systems which support higher rates of gain than in deferred systems and decreased with advancing age of the cattle.

Maternal heterosis (phase II). Phase II dealt with estimation of maternal heterosis expressed by F_1 cows compared to straightbred cows for reproduction and maternal traits. Phase II included 1,257 matings to produce six calf crops. Calf crop weaned was 6.4% greater for crossbred than straightbred cows. This difference was due to higher pregnancy rates and first service conception rate in the crossbreds. Differences in postnatal survival of calves were small and not significant in the second phase of the experiment when crossbred and straightbred cows were both raising crossbred calves.

Effects of maternal heterosis were 1.7% for birth weight, 3.6% for weight at 135 days and 4.3% for weight at 200 days (weaning). These effects of maternal heterosis did reflect greater and especially more persistent milk production favoring crossbred cows over straightbred cows by 0.9% at 2 weeks postpartum, 7.5% at 6 weeks postpartum, 6.1% at about 14 weeks postpartum and 38% at weaning at about 29 weeks postpartum. Actual weaning weight was 14.8% greater per cow exposed to breeding for crossbred cows than for straightbred cows on the average over both management regimes due to combined effects of maternal heterosis on reproduction and maternal ability.

c. Current Status:

- (1) The reciprocal cross and straightbred Angus, Hereford and Shorthorn cows involved in phase II were retained until November 1975 when they ranged from 12.5 to 15.5 years of age to evaluate effects of heterosis on longevity and lifetime production. It appears that further advantages will be accrued through greater longevity and lifetime production of crossbred cows relative to straightbreds. At 12 years of age 40 percent of the crossbred females remained in the herd while only 21 percent of the straightbred cows remained.

(2) Recent results on reciprocal cross and straight-bred Hereford, Angus and Shorthorn cows indicate that crossbred cows were 2.5% heavier at maturity than straightbred cows. Thus, feed requirements for maintenance should be slightly higher for crossbred cows than straightbred cows. However, this difference is small relative to the increased production of crossbred cows. Results have indicated that production per cow can be increased 23% by combined effects of heterosis on survival and growth of crossbred calves and by superior reproduction and milk production of crossbred cows. Only about 60% of the total benefit of heterosis could be realized if straightbred cows were required to continuously produce first-cross cows and replace themselves in a beef herd. An experiment has just been completed to determine the level of heterosis than can be sustained from one generation to the next by two- and three-breed rotational systems of crossbreeding relative to straightbred controls. Preliminary results indicate that substantial effects of heterosis are sustained by two- and three-breed rotational systems of crossbreeding. For example, palpation results after 1,107 total matings indicate pregnancy rates are 92% and 95% for two- and three-breed rotational systems compared to 87% for straightbred controls.

d. Research Plans:

- (1) The final calf crops in this project were produced in 1975 both by the phase II cows being evaluated for longevity and lifetime production and by the phase III cows.
- (2) Analyze and publish data which have accumulated or will soon be accumulated consistent with the objectives of this project:
 - (a) Data on postweaning growth and carcass traits of steers and heifers produced in phase II will be analyzed and published.
 - (b) Data on the first generation of phase III involving backcross and three-breed cross calves will be analyzed and published with particular attention to the level of heterosis expected in the different genotypes based on phase I and II results assuming dominance as the mode of gene action.

(c) Effects of heterosis on longevity and lifetime performance and in two-breed and three-breed rotations will be analyzed and published when data are obtained on the final calf crop.

4. Research Area:

Germ Plasm Evaluation Program

a. Objectives:

This program extends the evaluation of crossbreeding to a broad range of biological types and involves characterization of breeds representing different biological types in the full spectrum of economic traits. The major objective is to identify the appropriate biological types in regard to growth rate, milk level, mature size, shape of growth curve and other economic traits, for use in different production situations characterized by such factors as feed environment, managerial situation, labor availability, crossbreeding system and market requirements.

b. Procedure and Accomplishments:

(1) Procedure. The program was started in 1969. Cycle 1 included three calf crops (2,563 calves) born in 1970, 1971 and 1972. The first cycle involved breeding by artificial insemination Hereford, Angus, Jersey, South Devon, Limousin, Simmental and Charolais bulls to Hereford and Angus cows. All male calves were fed out as steers and slaughtered to evaluate growth, feed efficiency and carcass and meat traits. All female progeny were retained for evaluation of reproduction and maternal traits.

The second cycle included two calf crops (1,700 calves) born in 1973 and 1974. Brown Swiss and Red Poll female populations were added to the Hereford and Angus cow herds used in cycle 1. The Hereford and Angus females were bred by artificial insemination to Hereford, Angus, Brown Swiss, Red Poll, Maine-Anjou, Gelbvieh and Chianina bulls and the Red Poll and Brown Swiss females were bred to Hereford, Angus, Red Poll and Brown Swiss bulls. Information obtained on the second cycle of breeds is similar to that obtained on the first cycle.

Cycle 3 was initiated with the 1974 breeding season and will include approximately 1,400 calves born in 1975 and 1976. Hereford, Angus, Brahman, Sahiwal, Pinzgauer and Tarentaise sires were bred to the same Hereford and Angus cows used in cycles 1 and 2 of this program.

In addition to cooperation with the Nebraska Agricultural Experiment Station, University of Nebraska, this program involves cooperation with a number of other stations. Hereford-Angus, Jersey-Angus, Simmental-Angus and Charolais-Angus females (32 per breed group) were randomly selected at weaning and shipped to the Canada Department of Agriculture Research Station at Lethbridge, Alberta, where they and their progeny are being individually fed to evaluate efficiency of production.

The right side of each steer carcass has been shipped to Kansas State University to obtain detailed cut-out data and meat quality evaluation.

To evaluate genotype-environment interactions in diverse climatic and feed environments, cooperative efforts have been developed with other research stations. A sample of the F_1 females by Hereford, Angus, Brahman, Sahiwal, and Pinzgauer sires out of Angus and Hereford dams have been (1975) and will be (1976) transferred to the USDA, ARS and Florida Agricultural Experiment Station at Brooksville, Florida. The Louisiana Agricultural Experiment Station, Baton Rouge, is producing Brahman, Simmental, Maine-Anjou and Chianina F_1 calves using the same sires as used at the U. S. Meat Animal Research Center and out of Hereford and Angus cows formerly involved in the USMARC program. The U. S. Range Livestock Experiment Station (USDA, ARS and Montana Agricultural Experiment Station), Miles City, Montana, is producing Angus-Hereford, Red Poll-Hereford, Simmental-Hereford, and Pinzgauer-Hereford crosses. The same sires are used in these programs as have been used at the U. S. Meat Animal Research Center to evaluate sire by location as well as breed by location interactions for growth and carcass characteristics of steers and reproduction and maternal performance of F_1 females.

(2) Accomplishments. Some of the results from the first cycle of the program are:

(a) Gestation length, birth weight, dystocia level, calf mortality, preweaning growth and 200-day weight were studied in 2,368 calves. Charolais and Simmental crosses had faster preweaning average daily gains and were heavier at weaning, but also had larger birth weights and more dystocia. South Devon and Limousin crosses were similar in weaning weight to Hereford-Angus crosses, but were intermediate in birth weights and more like Charolais and Simmental crosses in level of calving difficulty. Jersey crosses were lightest at birth and weaning and experienced much less dystocia than other crosses. Gestation length was longest for Limousin ($288.1 \pm .69$ days) and shortest for Jersey ($281.8 \pm .73$ days) and Hereford-Angus ($282.9 \pm .39$ days) crosses. Preweaning relative growth rate was highest for Jersey, intermediate for Hereford-Angus and lowest for South Devon, Limousin, Charolais and Simmental crosses. Hereford by Angus heterosis was a significant effect for gestation length (-1.9 days), birth weight (.9 kg), 200-day weight (8 kg), ADG (.04 kg/day) and calf survival from birth to weaning (5.1%).

Dystocia level increased linearly with birth weight both across and within breed groups. Averaged over all dam ages, each 1 kg increase in birth weight within a breed group increased calving difficulty by $1.63 \pm .2\%$. Early calf death losses were 3.7 times higher in calves experiencing difficulty at birth than those born without difficulty ($11.5 \pm 1.52\%$ vs $3.1 \pm .99\%$). Calving difficulty did not influence ($P > .05$) calf survival from 24-hr postpartum until weaning. Sire variability in dystocia level was highly significant, even after removing average within breed differences in birth weight. Dam age and calf sex significantly influenced all traits. The influence of dam age on early calf mortality was accounted for by level of dystocia. Only dam age had an important influence on late calf mortality.

(b) Postweaning growth and feed efficiency was studied in 1105 steers. Differences were large for 405-day weight ($\pm 7\%$, range = 14%), average daily gain (ADG) ($\pm 9\%$) and relative growth rate (RGR) ($\pm 5\%$). Charolais and Simmental crosses, followed by South Devon crosses, were the largest, fastest gaining breed groups. Hereford-Angus crossbreds and Limousin crosses were similar in ADG and 405-day weight, while Jersey crosses were the smallest, slowest growing. South Devon and Simmental crosses had the highest RGR, while Limousin and Jersey crosses had the lowest. Breed group rankings were similar for ADG and RGR.

Feed efficiency was evaluated for breed groups fed in replicated pens in each of three years over age- (0 to 217 days on feed), weight- (240 to 470 kg) and grade- (0 days to 5% longissimus fat) constant intervals. Breed group differences were large for weight-constant ($\pm 10\%$), but reduced for age-constant ($\pm 5\%$) and grade-constant ($\pm 6\%$) intervals. ADG from 240 to 470 kg tended to explain relative ranking of breed groups for weight-constant feed efficiency. When tested against a significant breed-group by year interaction, Jersey crosses were less efficient than Charolais and Simmental crosses in the age-constant interval. Limousin crosses were least efficient, but not different ($P > .05$) from Simmental, Jersey, Charolais or South Devon crosses, when evaluated over a grade-constant interval.

(c) Carcass composition, quality and palatability characteristics in the steers revealed that breed crosses differed significantly in growth rate of retail product, fat trim, bone, quality grade and taste panel tenderness. Breed crosses that had the highest growth rate tended to have a higher percentage of retail product and bone and a lower percentage of fat trim than the slower growing breed crosses. Breed crosses that had higher growth rates also tended to have a lower percentage of fat (marbling) in the ribeye. Taste panel evaluation indicated all breed crosses had a high level of palatability and differences among breed crosses were small. Breed crosses that had higher marbling scores tended to have slightly higher taste panel tenderness scores. However, within breed groups the increased marbling associated with

time on feed did not result in an increase in taste panel acceptability, presumably due to decrease in tenderness associated with advances in age.

(d) Postweaning growth and puberty traits were studied in 965 heifers. Estrus was checked twice daily from 250 to either 480 or 510 days of age and age and weight at puberty were evaluated. Puberty was defined as date of first standing estrus followed by an estrus observed 17 to 23 or 34 to 46 days later.

Charolais, Simmental and South Devon crosses were the heaviest at 400 days of age followed closely by Hereford-Angus and Limousin crosses with Jersey crosses the lightest. Jersey crosses were 16% lighter than Charolais and 8.7% lighter than Limousin crosses at 400 days of age.

For percentage of heifers reaching puberty at each 30 day period from 300 to 450 days of age, breed crosses separated into three distinct groups. A higher percentage of Jersey crosses and a lower percentage of Charolais and Limousin crosses reached puberty with Hereford-Angus, South Devon and Simmental crosses intermediate throughout this age range. Breed crosses divided into the same three groups on the basis of average age at puberty. Charolais crosses were heaviest at puberty, followed by Limousin and Simmental, then South Devon and Hereford-Angus, with Jersey crosses the lightest.

These results indicate that Charolais and Limousin crosses reach a similar stage of physiological maturity at an older age and Jersey crosses at a younger age than other breed crosses represented in this study.

Heifers from Angus dams were 26 days younger and 20 lb lighter at puberty than those from Hereford dams. Heterosis in Hereford-Angus reciprocal crosses for age at puberty was 19.5 days with no effect on weight at puberty.

c. Current Status:

(1) Data collection are complete for preweaning and postweaning growth and for carcass traits of male animals in the first phases of cycle 1 and cycle 2.

(2) Females from the first and second cycles are presently being comprehensively evaluated for reproduction and maternal traits.

d. Research Plans:

Results from the characterization of a wide range of biological types represented in this program has and is providing the necessary information to determine the production performance which can be expected for a given biological type. This provides the basic information required to develop the understanding necessary to synchronize the available germ plasm capability to different resource and production situations. This involves three major components or areas to which this program is evolving: (1) establishment of nutritional and management requirements to optimize reproductive performance in animals representing different biological types, (2) establishment of nutritional and management requirements to optimize growth and carcass characteristics in the growing-finishing phase of production for different biological types, and (3) how to most effectively utilize the available germ plasm to more effectively utilize production resources and to more rapidly adjust the genetic resources to production and marketing changes.

5. Research Area:

Heterosis Retention

a. Objectives:

(1) Determine proportion of initial heterosis in individual and maternal performance of crossbreds retained in advanced generations of inter se matings from a crossbred foundation.

(2) Estimate genetic variation and potential rate of selection response in populations derived from crossbred foundations.

b. Progress:

Matings of unselected parents to produce contemporary groups of straightbred Angus and Herefords, reciprocal F₁'s, F₂'s, F₃'s and backcrosses of F₁ females to Angus and Hereford sires are being made. Linear contrasts of breed group means for major economic traits will provide estimates of individual and maternal heterosis and epistatic recombination effects associated with advanced generations of crossing.

c. Current Status:

(1) Multiple sire batteries of Hereford or Angus bulls in "clean-up" matings on the Hereford and Angus cows bred AI in the Germ Plasm Evaluation Program during the summers of 1972, 1973 and 1974 provided about 400 foundation females for the 1976 breeding season. Each year four bull calves from each breed group (HH, AA, HA and AH) with 200-day weights near the average of their breed group were designated for use in the experiment and the remainder was castrated for feedlot and carcass evaluation.

d. Research Plans:

(1) Complete matings to produce contemporary P_1 , F_1 , F_2 , F_3 and backcross groups through 1979 with completion scheduled for 1980.

6. Research Area:

Development of New Breeds of Beef Cattle Based on Multibreed Foundation

a. Objectives:

(1) To determine the feasibility of the development of new breeds based on multibreed foundation as an alternative to rotational crossbreeding systems to utilize heterosis; and as a method to make more rapid progress toward the optimization of gene frequencies for general "adaptability" to specific feed resource and market situations by use of the genetic variation among existing breeds, i.e., the selection between breeds.

(2) To evaluate the importance of epistatic recombination loss for economically important traits of beef cattle.

(3) To determine the amount of additive genetic variation for major economic traits that exists in populations formed by crossing and subsequent inter se mating involving existing breeds.

(4) To develop improved beef cattle germ plasm for industry use for conversion of specific feed resources and to meet specific market requirements.

b. Research Plans:

Research in this area is in the planning process. Information from the GPE Program on characterization will provide

the basis for identifying breeds to include in each population or new breed. At least two "all purpose" (maternal and paternal) breeds or populations that are phenotypically compatible for crossing with each other and one terminal sire (paternal) breed or population will be developed. "All purpose" breeds or populations will have performance level appropriate for average and above environmental conditions for reproducing animals with market animals having the capability to reach market weight and condition by 18 to 19 months of age on a ration averaging at least 70% corn silage from weaning to slaughter. Selection criteria and procedures appropriate for the objectives in all three populations will be developed based on comprehensive analyses of data from GPE and other programs. Control populations of the contributing parental breeds will be maintained simultaneously and subjected to the same selection criteria and procedures as the new populations. The unselected Hereford line from the Selection Project will serve as a control population for estimating selection response in both new and parental breeds.

7. Research Area:

Importance of Genetic Causes on Efficiency of Production

a. Objectives:

- (1) Determine genetic differences in shape of growth curve from birth to maturity.
- (2) Develop procedures to manage shape of growth curve to maximize production resource conversion rate.
- (3) Develop procedures for measuring net maternal ability in beef cattle involving such traits as puberty, calving ease, calving interval and weaning weight.
- (4) Development of programs (on-site and collaborative) in cytological, physiological and immunological genetics to explore genetic mechanisms regulating quantitative production traits.

b. Progress and Accomplishments:

Progress. Data from the heterosis study involving the Hereford, Angus and Shorthorn breeds have been used to study maturing patterns of body weight. Data are presently being collected in several of the projects to provide necessary information to evaluate genetic differences in shape of growth curve.

Information presently being obtained on the nutritional effects on puberty, fetal development, mature size, etc., will provide information for development of procedures on how to effectively manage shape of the growth curve to increase efficiency of production.

Accomplishments. Heterosis and reciprocal differences for immature weights (W), mature weight (MW), degree of maturity of body weight (u), absolute growth rate (AGR), absolute maturing rate (AMR), relative growth rate (RGR) and age at puberty (AP) were examined for 208 straightbred and crossbred Hereford (H), Angus (A) and Shorthorn (S) females. Average heterosis for MW was 2.5% ($P<.05$), but neither heterosis for specific 2-breed crosses nor reciprocal differences were significant for MW. The increased AMR's of crossbred calves through 550 days of age supported the hypothesis that a primary effect of heterosis is to speed up the maturing process. Heterosis for degree of maturity of body weight was significant at all constant ages except at birth. Reciprocal differences were generally unimportant for u, AMR, and RGR. Heterosis for RGR was significant ($P<.05$) only during the time of increased environmental stress.

Relationships among body weights, AGR, AMR, RGR and u were also examined for the 208 animals. Heritability of weight was 0.68 at birth, 0.59 at 200 days, 0.87 at 396 days, 0.82 at 550 days, 0.41 at 3-1/3 years, 1.00 at maturity and 0.44 at puberty (PW). The genetic correlations among weights were large ($r = 0.67$). Heritability of age at puberty (AP) was 0.64 ± 0.31 . The genetic correlation between AP and PW was 0.67 ± 0.24 . Heritability estimates for u declined from 0.73 at birth to -.26 at 3-1/3 years.

Animals growing most rapidly during the preweaning interval, in absolute terms (AGR) and relative to both current (RGR) and mature weight (AMR), tended to grow more slowly at later ages. Animals more mature at one age were generally more mature at all other ages. Variation in MW accounted for only 19% of the genetic variation in u through 550 days. Heritabilities were generally larger for RGR than AMR. An average of 50% of the variation in AGR was independent of MW. Correlations between all measures of growth in the same interval were positive but were generally negative between different intervals. Thus, selection for increased growth rate over any age interval, in either absolute or relative terms, would tend to alter the shape of the growth curve over the interval of selection. However, selection for AGR would increase weight at all ages, while selection for preweaning RGR would tend

to decrease BW and weight subsequent to 550 days, but increase 200-, 396- and 550-day weights.

c. Current Status:

The area of growth curve evaluation is not presently being studied on a comprehensive basis except as it fits within the framework of specific projects.

d. Research Plans:

- (1) The area of growth curve evaluation and management will be developed as a specific research area and will encompass data obtained from several existing projects. This area will include a high level of input from the disciplines of genetics, management systems and nutrition.
- (2) Development of programs in cytologic, physiologic and immunologic genetics will progress as specific needs and opportunities warrant. For example, the probability of a new breed contributing different genetic material relative to previously evaluated breeds could be determined by establishing cytogenetically whether the breed in question has a different genetic composition than breeds which have been evaluated.

II. NUTRITION

A. General Objective. Develop understanding necessary for production programs to most effectively meet nutritive requirements for both growing-finishing and reproducing animals involving a wide range of biological types in regard to performance characteristics. Efforts will be oriented toward maximum utilization of pasture and forage in life cycle production systems and the use of NPN as a major source of supplemental nitrogen for both growing-finishing and reproducing animals.

B. Specific Programs.

1. Research Area:

Nutrient Requirements for Optimum Reproduction in Different Biological Types of Cattle

a. Objectives:

- (1) To determine nutrient requirements necessary to support optimum performance in females of different biological types varying widely in lactation potential and mature size.

- (2) Determine effects of nutritive environment at different stages of the life and reproductive cycle on prenatal survival and development, gestation length, calving difficulty, calf survival and growth, milk production, postpartum reproduction and resultant performance of offspring in breeding and/or feedlot.
- (3) Determine the extent of genetic differences, both within and among biological types, for intrinsic efficiencies of maintenance, growth, gestation and lactation.
- (4) Develop the necessary information to synchronize such biological parameters as cow size, milk level, growth rate, mature size and reproduction with a wide variety of feed resource and production situations.

b. Procedure and Accomplishments:

An experiment was initiated in 1975 to determine the effect of energy level during gestation on maternal and fetal rates of gluconeogenesis (see item 2.c.1. in Reproduction).

c. Current Status and Research Plans:

A comprehensive program directed toward determining the nutrient requirements for optimum reproduction in different biological types of cattle is being planned. This project will include major inputs from the disciplines of nutrition, reproduction, genetics and breeding, and management systems. Analysis of weight changes, milk production and reproductive performance in the F_1 cows produced in cycle 1 of the GPE program will provide the basic guidelines for expansion of this research area.

2. Research Area:

Nutrient Requirements and Feeding Systems for Different Biological Types of Growing-Finishing Cattle

a. Objectives:

- (1) Determine if animals with a higher genetic growth potential have different energy and protein requirements than those growing less rapidly and if so, when these requirements are most critical in the growing-finishing program.

- (2) Develop optimum feeding program to obtain optimum carcass characteristics and feedlot performance, to maximize yield of edible product per unit of feed resource used.
- (3) Develop an understanding of lipid metabolism in different biological types of animals fed on different nutritional regimes and their relationship to lipid deposition and carcass quality.
- (4) Determine the optimum nutrition program to obtain the most desirable carcass for each biological type.
- (5) Determine if rumenoreticular capacity and rate of passage have been limiting optimum performance under current and previous feeding regimes.
- (6) Determine if there is a difference in protein requirements (higher early or lower late in the growing-finishing program) at different ages and weights with respect to levels of energy and biological type.
- (7) Determine the effect of source (type of feed) of nutrient on animal performance and efficiency.

b. Procedure and Accomplishments:

Experiments have been completed to determine if animals with different genetic capability for growth have different requirements for dietary energy and protein. These experiments involved over 1,200 steers ranging in type from Hereford-Angus crosses to 7/8 Charolais. Rations varied from 80% roughage (corn silage) and 20% concentrate to 20% roughage and 80% concentrate.

Results from these experiments show that increasing dietary energy levels above 40% concentrate and 60% corn silage increased live weight gains, and thus carcass weight, but over 80% of this increase in carcass weight was fat. In addition, increasing the amount of fat in the carcass did not affect taste panel acceptability.

Research with varying dietary energy levels has shown that steers fed 20% corn silage and 80% concentrate compared to 60% corn silage and 40% concentrate gained faster when fed the higher concentrate ration and had increased dry matter conversion, quality grade

and quantity of boneless edible beef. However, at the same time, increases in pounds of carcass fat (21%) and abscessed livers (15%) were observed with the higher concentrate ration. These results show that carcass composition can be affected by the concentrate level of the ration. This research is designed to provide information for the beef producer so that he can produce a highly desirable edible product utilizing a high proportion of available roughages in the finishing program.

Results to date indicate that for weaning calves weighing 500 to 600 lb, dietary protein levels up to 13% dry matter are needed during the first 145 lb of the growing-finishing period for smaller types (Angus-Hereford crosses) and during the first 170 to 220 lb for larger, later maturing types (Charolais). Cattle fed a level of 10% dietary protein during this period showed a 16-25% depression in growth. However, cattle in excess of 725 to 800 lb showed no difference in growth when fed a 10% protein ration during the remainder of the growing-finishing period. Attempts to remove all supplemental protein at 750 lb body weight greatly reduced growth in cattle fed all corn silage rations but have only slightly reduced growth in cattle fed high-concentrate rations. Economically, cost of gain can be reduced by feeding higher levels of dietary protein (13.0%) during the early phase of the growing-finishing period and lower levels (10.0%) during the later phase of the growing-finishing period.

c. Current Status:

Three experiments were initiated in 1975 and will be completed in 1976:

- (1) A factorial design consisting of a 3 x 3 for the larger type cattle and a 2 x 3 for the smaller type cattle with all treatments replicated was utilized. This involves 15 treatments, 30 lots and 180 cattle. Variables are two types of cattle (18 lots of the larger, later maturing Charolais, Gelbvieh, Maine-Anjou and Brown Swiss crosses vs. 12 lots of the smaller, earlier maturing A x H Reciprocal crosses); three levels of protein (13%, 13% changing to 10% and 13% changing to no supplemental protein (NSP) expressed on a dry matter basis) for the larger, later maturing cattle and two levels of protein (13% plus 13% changing to NSP) for the smaller, earlier maturing cattle and three levels of energy (maximum, maximum changing to 60% and 60% corn silage). The protein and energy ration changes will occur when the cattle lot averages 750 pounds.

(2) Two biological types of steers (large, late maturing vs. small, early maturing) are being evaluated on five feeding regimes. Each type by feeding-regime group is replicated once, except that replicates of regimes (a) and (b) are paired until after the grazing period.

The following feeding regimes are being used:

- (a) Winter growing ration of 48% corn silage, 50% alfalfa haylage and 2% supplement designed to produce daily gains of 1.25 to 1.40 lb, followed by about 150 days grazing on cool and warm season pastures and then 98 days on a 60% forage ration.
- (b) Same as regime (a), except the final ration will be only 20% forage.
- (c) Complete forage ration, except for 1.75% supplement and 1.60% soybean meal.
- (d) Same as regime (c), except a 60% forage ration will be fed the last 98 days.
- (e) A 60% forage ration for entire feeding period.

All rations other than the growing rations in regimes (a) and (b) contain 20% alfalfa haylage with corn silage as the balance of the forage and with enough soybean meal added to provide 13% crude protein. Supplement was added to each ration at a level which allows 0.6 lb/head/day consumption. Steers on pasture were fed a salt mixture containing antibiotic, vitamins and trace minerals at rates similar to cattle in the feedlot.

Expected mature weights for females of these biological types are 1,050 to 1,100 for the smaller type and 1,200 and 1,250 for the larger type. Serial slaughter techniques designed to kill steers at approximately 90% and 105% of this expected mature size were employed. An additional slaughter of steers on regimes (a), (b) and (d) was made at the beginning of the higher concentrate feeding period.

(3) An experiment utilizing a small sample of Angus, Charolais and Limousin steers was initiated in 1975. Steers are maintained in individual stanchions and biopsies of subcutaneous and perirenal fat taken at monthly intervals from weaning to slaughter to determine effect of biological type on rate of lipogenesis and lipolysis at different points

during the growing-finishing period. The rate of lipogenesis and lipolysis at the time of slaughter are being determined in the animals used in the experiment described under item 1 of this section.

d. Research Plans:

- (1) Complete the experiments in progress.
- (2) Continue efforts in this area to develop optimum feeding and management programs for different biological types of cattle in the growing-finishing phase. This will involve the major nutrients and will be oriented toward maximum utilization of roughages.

3. Research Area:

Relationship of Metabolites in Blood and Urine to Production Parameters

a. Objectives:

Find blood and/or urine metabolites which can be utilized as predictors of an animal's potential for growth, efficiency of nutrient utilization and/or carcass composition.

b. Progress:

During the past year experimental procedures have been developed in sheep that can be used for later studies with cattle.

c. Current Status:

- (1) Work is currently progressing on establishing optimal conditions for separating 50 to 100 urine metabolites by liquid chromatography.
- (2) Also, preliminary work is being done to establish the optimal methods and length of time required to obtain representative urine samples.

d. Research Plans:

Experiments will be conducted to determine if growth rate and feed efficiency are related to urinary and blood metabolites in animals of different biological type.

4. Research Area:

Increasing Utilization of NPN

a. Objectives:

- (1) Obtain an understanding of the biochemical alterations in intermediary carbohydrate and amino acid metabolism which account for the decreased performance of animals fed high levels of NPN.
- (2) Develop new methods of improving productive performance of animals fed NPN.

b. Progress:

- (1) Initial studies have been conducted on sheep because of labor and cost considerations of feeding purified or semipurified rations to cattle. Experiments to date have indicated that high levels of dietary NPN does not affect glucose turnover, but urinary citrate excretion is increased 5 to 10 fold. The quantities of citrate excreted in the urine appear to be related to the urea fermentation potential of the ration. The excretion of this metabolite may prove to be an indicator of the optimal levels of NPN to include in any particular type of ration.
- (2) The effects of frequency of feeding (12 vs. 2 times daily) on utilization of NPN has been studied. The more frequent feeding initially aids in adaptation of the animals to high levels of NPN and results in a lower excretion of urinary citrate.

c. Current Status:

Additional experiments are planned and will be initiated.

d. Research Plans:

- (1) Establish the quantities of amino acids absorbed from the gastrointestinal tract of animals fed NPN vs. preformed protein.
- (2) Establish the cause of the increased urinary citrate excretion in NPN fed ruminants.

5. Research Area:

Nutrition and Management of Early Weaned Calves

a. Objectives:

- (1) Determine nutritional requirements of calves from

30 to 60 days of age to normal weaning age and to evaluate the effects of early weaning nutritional regimes on postweaning growth in males and on reproductive performance in females.

- (2) Develop optimum nutrition, herd health and management procedures for early weaned calves.

b. Procedure and Research Accomplishments:

- (1) Fall-born calves (293) representing seven breed groups were used to determine the effects of weaning age (56, 112 and 168 ± 21 days) and energy composition of the ration on calf performance. Results indicate that calves can be weaned at young ages to dry feed and will perform equal to, or slightly better, than calves nursing their dams. Calves weaned at 50 to 75 days of age gain better than those weaned at 35 to 50 days of age. Performance is better from 56 to 112 days of age on a ration containing 70% TDN than on a ration containing 80% TDN (1.98 vs. 1.73 lb/h/d). Time of weaning had no influence on gain from 200 days of age to slaughter weight in males or breeding age in females. However, early weaning (56 ± 21 days) tended to increase age at first breeding and age at conception compared to calves weaned later. A second study has substantiated that calves can be successfully weaned at 35 to 75 days of age.

c. Current Status:

- (1) No studies in this area are currently in progress.

d. Research Plans:

- (1) Future studies in this area will be directed toward determining more precisely the nutritional requirements of the major nutrients for the early weaned calf.
- (2) Management systems studies will be implemented to determine the relative importance of early weaning as an economical management practice as it relates to such factors as increased rebreeding performance of cows, reduced cow feed costs by utilizing low quality roughages and reduced energy intake in dry, gestating cows as opposed to increased costs for feed and management for early weaned calves. Results of these studies will determine the amount of emphasis given to this area during the next 3 to 5 years.

III. REPRODUCTION

A. General Objective. Develop a comprehensive research program involving both the male and female components of the reproduction cycle to gain the understanding necessary for increasing the number of market animals produced per breeding unit maintained.

B. Specific Programs:

1. Research Area:

Influence of Management, Biological Type, Growth Rate and Hormone Levels on Puberty, Ovulation, Estrus and Conception

a. Objectives:

(1) To evaluate genetic, nutritional and management factors on reproductive performance in the young female (prenatal development stage to 2 years of age).

b. Procedure and Accomplishments:

(1) Yearling heifers (900) representing 20 breed groups were used to determine the effect of insemination time, relative to the onset of standing estrus, on conception and to evaluate estrous behavior in a wide range of breed groups. Results show that heifers can be inseminated from 4 to 12 hr. after the onset of standing estrus with no effect on conception. Estrous behavioral patterns were similar among domestic beef breeds, dairy breeds and crosses, and the new breeds (exotics) represented in the first cycle of the GPE program.

(2) It was demonstrated in a study designed to determine effective estrus detection procedures for artificial insemination programs that penectomized bulls equipped with chin-ball markers can be effectively utilized to increase the accuracy and to reduce the labor requirement of estrus detection. The most effective ratio appears to be approximately 30 cows/bull, resulting in a detection rate ranging from 95 to 100%. As the ratio of cows/bull increases, the percentage of cycling cows marked decreases, the number of cows marked/bull increases, and the degree of marking becomes increasingly lighter and more difficult to observe.

(3) Extremes in temperature appear to have only a limited effect on the occurrence of estrus and detection. The relatively minor differences observed can be attributed to a reduction in activity by the cows and perhaps less effective observation by heat detection personnel. However, temperature change (fluctuation) does appear to be associated with the distribution of estrus. High temperature fluctuations were associated with a greater number of cows being detected in heat, while a lack of temperature change resulted in decreased estrus activity.

Results from this study indicate that once a day estrus detection for artificial breeding would result in a significantly reduced percentage of cows being bred.

c. Current Status:

Data are being analyzed to evaluate effects of biological type and growth rate on age at puberty and conception.

d. Research Plans:

- (1) A high percentage of the efforts in this area will be an integral part of the characterization of the different biological types in the GPE program as efforts in this area are intensified.
- (2) Major effort will continue to be directed toward determining effects of genetic, environmental and management factors on puberty and conception and how to optimize these factors to increase reproductive efficiency.

2. Research Area:

Dystocia and Perinatal Mortality

a. Objectives:

- (1) Determine the effects of dystocia (calving difficulty) on calf mortality and on postpartum rebreeding in the cow.
- (2) Determine factors that influence dystocia and determine their magnitude of influence.
- (3) Determine if dystocia can be practically predicted.
- (4) Develop methods for decreasing dystocia.

b. Procedure and Accomplishments:

- (1) A study involving 5,064 parturitions and 18 breed groups showed that calf losses at or near the time of birth were four times higher in calves experiencing dystocia (20.4%) than in those not experiencing dystocia (5.0%). Postpartum rebreeding information on 1,889 cows showed that dystocia decreased the percentage of cows exhibiting estrus during a 45-day AI period by 14.4%, decreased pregnancy rate to AI by 15.6% and decreased percentage pregnancy to a 45-day AI plus a 25-day natural breeding period by 15.9%.
- (2) Calves from Hereford and Angus cows (1,872) bred to seven breeds of sires were used to study factors affecting dystocia. Sire breed, dam breed, cow age, calf sex and birth weight significantly affected dystocia. Dystocia increased 1.1% for each pound increase in calf birth weight. When birth weight was held constant in the analysis, dam age was the only main effect significantly associated with dystocia and sire breed was the most important variable influencing calf birth weight.
- (3) Factors associated with pelvic area were studied in 943 yearlings and 2-year-old cows and factors associated with dystocia were studied in 599, 2-year-old primiparous cows. Variables studied in relationship to pelvic size were breed, precalving energy level, age, cow weight, weight change, condition score, muscling score and pelvic slope score.

Factors studied in relation to dystocia were breed, precalving energy level, pelvic height, pelvic width, cow weight, calf sex, calf birth weight, calf shoulder width, hip width, chest depth, wither height and body length. Cow weight was the largest source of variation associated with pelvic area, but breed, adjusted for cow weight, had a significant ($P < .01$) effect on pelvic area. Traits known or measured before parturition accounted for 26% of the variability in percentage of dystocia in the 2-year-olds representing the 14 breed groups and 5% in the 2-year-olds fed three levels of energy before calving. The amount of accountable variability associated with dystocia was increased to 39 and 25% in the two groups of cows when calf

sex, birth weight and the five calf shape measurements were included in the analysis. Results of this study indicate that the relationship between dystocia and the physical measurements and subjective scores of cows included in this study are too low for these variables to be used as accurate predictors of dystocia. Larger 2-year-old cows have larger pelvic openings, but they also have calves with heavier birth weights. Although differences in dystocia rates among breeds with similar birth weights suggest calf anatomy as a possible effect on dystocia, calf shape measurements taken in this study, independent of birth weight, were not related to dystocia.

- (4) Hereford and Angus yearling heifers (362) were fed three levels of energy during the last trimester of gestation to determine effects of energy on calf birth weight, dystocia, and rebreeding performance. Cow weight gains for the three energy groups were 0.6, 1.4 and 2.0 lb/head/day. Energy level significantly affected calf birth weight, but had no influence on dystocia. Interval from calving to first estrus was 10 days longer ($P < .03$) in the low than the high energy level, but there was no difference in percent pregnancy at the end of a 65-day breeding period. In addition, 162 yearling heifers of the Angus, Red Poll, Charolais, Simmental (1/2), Limousin (1/2), and Brown Swiss breeds were used to determine the influence of three energy and two protein levels during the last trimester of gestation on birth weight and dystocia in cows varying widely in biological type. Neither energy nor protein level affected dystocia, but there was some indication that energy level may affect perinatal calf mortality.

c. Current Status and Research Plans:

- (1) The first study of a comprehensive program is in progress to evaluate the effects of different nutrients on prenatal development. One experiment is designed to evaluate the effects of energy on placental, uterine and fetal development from 90 to 270 days of gestation with the objective of determining the stage of parturition at which fetal development might be altered by nutritional influences. One-hundred-twenty Hereford, Angus

and Red Poll cross heifers, mated to Brown Swiss bulls, are being fed to gain 0, 1.0 or 2.0 lb per day from 35 to 270 days gestation. Five heifers from each energy level are slaughtered at 90, 120, 150, 180, 210, 240, 255 and 270 days of gestation. This experiment has major inputs from the disciplines of nutrition, carcass and meats and physiology.

The magnitude and economic importance of dystocia problems in beef cattle and the restrictions this problem places on the utilization of the large sire breeds for crossbreeding programs makes it imperative that management procedures be developed to minimize dystocia.

3. Research Area:

Postpartum Rebreeding

a. Objectives:

- (1) To determine the effect of lactation, level of milk production, and nutritional status on postpartum rebreeding performance.
- (2) To determine the relationship of lactation and level of milk production to hormonal function in the postpartum cow.
- (3) To gain the understanding of the physiological and environmental factors necessary to shorten the interval from parturition to conception.

b. Procedure and Accomplishments:

- (1) Three-hundred-eight Hereford, Angus, Charolais-cross (Charolais-Hereford and Charolais-Angus), Red Poll and Brown Swiss cows ranging in age from 2 to 11 years were used to investigate the effects of weaning 1 week before the beginning of the breeding period on postpartum reproduction. Weaning increased overall conception in the 42-day breeding period by 25.9% in 2-year-old cows, 15.6% in 3-year-olds and 7.9% in cows 4 years old and older (mature cows). There were 13.8% more 2-year-old cows and 15.6% more mature cows pregnant at the end of the first 21 days of breeding in the weaned than in the nonweaned groups, but these differences were not statistically significant. Weaning increased the percentage of cows exhibiting estrus from calving to the end of the breeding period by 29% in 2-year-olds, 26.7% in 3-year-olds and 16.3% in mature cows. Weaning

also increased the percentage of cows exhibiting estrus during the first 21 days of breeding by 39.2% in 2-year-olds and 23.5% in 3-year-olds, but it had no influence on the occurrence of estrus in mature cows. The increased percentage of the cows from the weaned group that conceived during the 42-day breeding period was the result of the effects of weaning on the occurrence of estrus, rather than on conception rate among those inseminated.

- (2) Effect of energy level in weaned and nonweaned cows indicated that weaning is far more important than energy level in affecting postpartum estrus and rebreeding. This indicated that lactation in the early postpartum cow affects reproduction by a means other than the nutritional requirements for lactation.
- (3) A series of experiments have been conducted to determine the effect of lactation, level of lactation, cow age and breed on ovarian and pituitary function; i.e., to determine if the postpartum cow does not exhibit estrus and ovulate before 60 to 70 days postpartum because the ovary or pituitary will not respond to an appropriate stimuli. The ovaries and the pituitary of lactating and non-lactating young and mature cows responded to exogenous hormones suggesting that only the mechanism to initiate the postpartum estrus is the limiting factor in decreasing the postpartum interval.

c. Current Status:

Other studies are in progress to further evaluate the effect of lactation on reproductive performance of the postpartum cow. One of these is directed toward determining the effect of suckling intensity on spontaneous LH release and the effect of LH as a limiting factor in initiating the postpartum estrous cycle. A study to evaluate the effect of lactation level on pituitary and ovarian function is being completed.

d. Research Plans:

Efforts will continue in this area and will be integrated with other disciplines to develop treatment regimes and management practices to decrease the interval from parturition to conception.

4. Research Area:

Sources and Causes of Pregnancy Losses

a. Objectives:

- (1) To determine if pregnancy losses are due to ovulation failure, fertilization failure, abnormal cleavage, abnormal embryonic development or to the uterine environment and to determine the proportion of the losses attributable to each of these factors.
- (2) To characterize the biological environment associated with implantation or implantation failures by measuring the biochemical components of the uterine luminal fluid and uterine endometrium.
- (3) To determine the factors which control the uterine environment making it blastotrophic or blastolytic.
- (4) To determine causes of pregnancy losses in cows ovulating two or more ova.

b. Procedure and Accomplishments:

- (1) Two studies directed toward inducing multiple births in beef cattle by the injection of hormones have been completed at the U. S. Meat Animal Research Center. One of these studies further substantiated that multiple ovulation and cleavage can be accomplished by the use of exogenous hormones. It appears that early embryonic mortality is one of the major reasons twinning cannot be successfully accomplished on a practical basis at this time. In a study involving 134 yearling heifers, abortions had occurred in 20% of the heifers by 90 days postbreeding. In a second study, involving 152 mature cows, over 50% of the cows ovulated more than one egg, but only eight sets of twins and one set of triplets were born.
- (2) Data from the U. S. Meat Animal Research Center show that conception in cows exhibiting estrus is 55 to 60% to AI and 65 to 70% to natural service per estrus. A series of studies were initiated to determine sources and causes of conception losses. Potential sources of losses which were identified to investigate were:
 - (a) ovulation failure in cows exhibiting estrus;

(b) fertilization failure which could be due to variation in time of ovulation relative to standing estrus, resulting in poor timing of sperm deposition relative to ovulation; (c) abnormal development of the zygote and blastocyst; and (d) the uterine environment was not receptive to the conceptus.

Results from several experiments indicate that ovulation occurs in 98% of all beef cows detected in standing estrus. It has also been shown that variation in time of ovulation relative to onset of estrus is not a primary source of conception loss. Yearling heifers were used to study the relationship of onset of standing estrus, pre-ovulatory LH surge and ovulation. Heifers were laparotomized 26 and 30 or 30 and 36 hr after onset of standing estrus. Average interval from onset of estrus to ovulation was 31.3 ± 0.6 hr. Average interval from onset of estrus to peak LH was 2.5 ± 0.9 hr and from peak LH to ovulation was 28.7 ± 0.7 hr.

Ovum and blastocyst development were studied in 79 heifers slaughtered 2, 3, 6, 12 and 15 days postmaturing. Ova or blastocysts were recovered from 67% and fertilized ova or normal blastocysts were found in 91% of those recovered. Thus, pregnancy in cows exhibiting estrus is 55 to 60% per estrus when bred artificially and 65 to 70% when bred naturally. Results of a comprehensive study show that ovulation failure, variation in time of ovulation, fertilization failure and abnormal ovum development account for less than 10% of this 30 to 40% pregnancy loss. The remaining losses (20 to 30%) occur from fertilization to 12 days after breeding.

The relationship of uterine endometrial proteins to pregnancy has been studied in approximately 200 yearling heifers from Day 2 to Day 48 postmaturing. It has been determined that there is an association between a specific uterine protein and pregnancy and that this association is detectable by Day 12 postmaturing. This association was determined by producing an antibody to the specific uterine protein and evaluating the presence of the antigen in heifers classified as pregnant and open. The association is quantitative and preliminary data indicate that the uterine endometrium of pregnant heifers contains approximately twice as much of the protein as non-pregnant heifers by Day 15 postmaturing.

Ovariectomized heifers are being used to determine the effect of exogenous hormones on uterine endometrial protein synthesis.

c. Current Status and Research Plans:

- (1) Studies are in progress to determine: (a) if the higher concentration of the endometrial protein in pregnant heifers is causative or if it is a result of the presence of the conceptus in the uterus, (b) what controls its synthesis, and (c) to purify the specific protein.
- (2) Studies have been initiated and a comprehensive program will be developed to determine the ovum-sperm relationship to conception.

5. Research Area:

Male Reproductive Performance on Conception

a. Objectives:

- (1) Develop adequate criteria and procedures to effectively determine age at puberty in bulls.
- (2) Determine effects of libido and semen characteristics on conception by natural mating and develop procedures to predict and control these to increase conception.
- (3) Determine the sperm-ovum and female reproductive tract relationships that affect fertility and blastocyst development.

b. Procedure and Current Status:

- (1) In an experiment initiated in 1975 bull calves were used to study the relationships of libido, testicular consistency, seminal characteristics, and plasma hormones to onset of puberty in Angus, Hereford, Red Poll, Brown Swiss, Angus x Hereford, and Hereford x Angus. The bulls were evaluated biweekly for seven months from weaning to 13 months of age. Results of this study are being summarized.
- (2) A study will be initiated in 1976 to (a) investigate the effects of insulin and exogenous androgens (testosterone, dihydrotestosterone, and androstenedione) on the motility, metabolism, morphology and ultra-structure of bovine spermatozoa; (b) determine the amount and specificity of hormone binding by bovine spermatozoa and seminal fluids; and (c) utilize cytochemical techniques to localize and identify the hormone receptor sites of bovine spermatozoa.

c. Research Plans:

A comprehensive program is being initiated in this area. A large part of this effort will be highly integrated with efforts to determine sources and causes of conception losses in the female. Studies will be initiated to evaluate the effect of the female reproductive tract on sperm morphology.

6. Research Area:

Role of Androgenic Hormones on Muscle Growth

a. Objectives:

- (1) Establish the relationship of the hypothalamus-pituitary-androgenic axis in male cattle.
- (2) Determine the relationship of testosterone and androgen metabolites to protein synthesis and deposition.
- (3) Evaluate interactions of hormones and nutrition in influencing rate of growth and carcass composition.
- (4) Develop procedures for optimizing the hormonal balance in males to increase feed efficiency and increase the lean-to-fat ratio while maintaining desirable meat quality.

b. Current Status and Research Plans:

- (1) Studies have been initiated to determine detectable levels of androgens and androgenic metabolites in peripheral plasma of the bull and to establish the relationship of these to each other. Blood samples were collected from the peripheral circulation and the spermatic vein to determine the presence and levels of different steroids and androgenic metabolites in the bull and the effect of LHRF on the secretion and release of these steroids.
- (2) Studies are planned and will be initiated this year to determine the role of androgens in protein synthesis and deposition.
- (3) A comprehensive program is being initiated to achieve objective 4. Efforts will include major inputs from the muscle biology and meats area. As the program develops, efforts will be highly integrated with the disciplines of nutrition, management systems and genetics as well as muscle biology and meats.

IV. CARCASS AND MEATS

A. General Objective. Develop the understanding necessary for increasing the percentage of carcass edible portion and quality of the meat through changes in production system. Efforts will be highly integrated with all other disciplinary interests represented at the U. S. Meat Animal Research Center.

B. Specific Programs.

1. Research Area:

Develop Procedures to Determine Composition of the Live Animal and the Carcass

a. Objectives:

- (1) Evaluate and improve procedures for live animal evaluation of body composition.
- (2) Evaluate and improve techniques to measure carcass composition.

b. Research Accomplishments or Progress:

- (1) Visual appraisal of 14 feeder calf traits on 449 feeder calves representing a wide range in biological type were analyzed as predictors of subsequent carcass qualitative and quantitative characteristics. No combination of feeder calf traits produced a meaningful estimator of carcass quality grades. Visual scores accounted for 41% of the variation in percentage actual cutability. Higher carcass cutability was associated with lower feedlot rates of gain.
- (2) Visual appraisal of 452 slaughter steers of 14 breed groups, representing a wide range in biological type, was made to evaluate criteria for characterizing body composition and carcass quality. Prediction equations developed from these data indicate that the best combination of visual scores only accounted for 13% of the variation in carcass quality grades over all breed types and only 5% within breed types. Prediction equations using live animal scores accounted for 51 and 65% of the variation in carcass yield grade and percent actual cutability on an overall basis and 28 and 37% within breed groups.

- (3) Twenty-seven steers obtained by mating Hereford, Simmental and Limousin bulls to Angus cows were slaughtered after 200, 242 and 284 days on feed to develop accurate, reliable predictors of carcass chemical composition. Multiple regression equations involving traits observed in the cooler, carcass cut-out and rib chemical analyses accounted for 87, 93 and 97% of the variation of carcass moisture, fat and protein, respectively. These equations work equally well for the three breed groups and lengths of time on feed.
- (4) The same 27 carcasses indicated above (3) were evaluated for organoleptic traits. Correlation coefficients between carcass chemical composition and palatability traits were low. Linear regression coefficients indicated little or no association between chemical composition and growth rate or palatability.
- (5) Carcasses from 1,121 steers (progeny of Hereford or Angus cows mated to Hereford, Angus, Charolais, Simmental, Limousin, South Devon or Jersey sires by artificial insemination) were examined to develop equations to estimate percentage of retail product. The independent variables chosen and resultant accuracy of the equations developed, reflect different kinds of measurements which could be used to predict cutability over a wide range of data collection conditions.

Of 18 traits readily obtained in the cooler, adjusted fat thickness, longissimus muscle area, estimated kidney and pelvic fat, hot carcass weight and marbling score were the most important in predicting percentage of retail product. A multiple regression equation involving these five independent variables accounted for 79.2% of the variation in percentage of retail product with a standard error of +2.05.

Partial retail cutout of the round or the rib was important ($P < .01$) in predicting retail product when included in equations with carcass parameters observed in the cooler. A multiple coefficient of determination of .895 and a standard error of +1.44 were observed over all breed of sire subclasses in an equation utilizing adjusted fat thickness, actual percentage of kidney and pelvic fat, percentage of round retail product and percentage of chemical fat in the soft tissue of the 9-10-11th rib as independent variables.

Results showed that adequate alternatives exist to complete processing of carcasses to determine yields of retail product. Reasonably precise estimates of percentage of retail product can be made based on prediction equations involving independent variables measured on carcasses in the cooler alone or in combination with partial cutout data. These estimates should be especially useful when a large number of carcasses are to be evaluated.

(6) A study to evaluate the use of the EMME lean measurement technique to predict composition in carcass beef was conducted in cooperation with Iowa Beef Processors, Dakota City, Nebraska. Choice grade carcasses from 66 animals were evaluated. Repeatability of EMME measurement indicates that one reading should be sufficient. Side carcass weight accounted for 93% of the variation in pounds of lean cuts + lean trim, side weight + fat thickness accounted for 96% and side weight + fat thickness + EMME 97% of the variation.

(7) Four-hundred-eighty-four steers, obtained by mating sires of seven breeds and dams of two breeds (Cycle 1, GPE Program) were used to evaluate cannon bone size, or "ruggedness" as related to performance and carcass traits. Size of bone scores were determined on the steers just after weaning and just before slaughter, and right forecannon circumferences were measured at slaughter time. Bone ruggedness, scored just after weaning, was highly related to bone ruggedness scored just before slaughter ($r = .80, P < .01$) and to forecannon circumference at slaughter time ($r = .67, P < .01$). Slaughter bone ruggedness was also highly related to slaughter forecannon circumference ($r = .77, P < .01$).

Breed crosses differed ($P < .05$) in bone scores, forecannon circumference, and carcass bone percentage. Generally, breed cross rankings for feeder calf ruggedness scores closely paralleled rankings for slaughter ruggedness scores and slaughter forecannon circumferences. However, except for the two most rugged crosses having the highest carcass bone percentages, breed cross rankings for carcass bone did not correspond with breed cross rankings for feeder or slaughter ruggedness scores or for forecannon circumference.

Correlations calculated over all breed crosses indicated that cannon bone size evaluations were positively correlated ($P<.01$) with birth weight, 200-day weaning weight, feedlot ADG, and slaughter weight (range, .21 to .60). Cannon bone size was positively correlated ($P<.01$) with cutability and retail product percentages (range, .25 to .42), but negatively correlated with longissimus marbling score, quality grade, and carcass fat percentage (range, -.18 to -.39). Cannon bone size was also positively correlated ($P<.01$) with carcass bone percentage (range, .15 to .31).

Pooled within breed cross correlations were considerably lower than correlations calculated over all breed crosses. Within a breed cross, feeder bone ruggedness score and slaughter forecannon circumference were not related to carcass composition traits. Cannon bone size was more highly related to performance and carcass traits when considering all breed types than it was for cattle within a given breed type.

(8) Various measurements were taken on metacarpal bones of 484 steers of different breed crosses and types to evaluate relationships with live appraisal of cannon bone size and right forecannon measured circumference. Breed crosses with the highest bone scores and forecannon circumference also had the largest metacarpus circumference. Pooled overall breed cross correlations of metacarpus circumference with cannon size scores and forecannon circumference ranged from .57 to .67.

Breeds with larger metacarpus circumferences generally had larger marrow cavity areas but did not have thicker bone walls. Over all breed crosses, marrow cavity area was highly significantly correlated with cannon size scores (range, .42 to .58), while bone wall thickness was not significantly ($P<.05$) correlated with cannon size scores (range, -.03 to .05). Ratios of total cross-sectional area to marrow cavity area (TA/MCA) indicated that breed crosses with smaller metacarpi have more bone wall area in relation to total cross-sectional area than breed crosses with larger metacarpi. The ratio of TA/MCA was inversely associated with cannon size scores, and correlations of TA/MCA with cannon size scores were negative ($P<.01$). Specific gravity differences among crosses were mostly nonsignificant ($P>.05$).

When correlations between cannon bone size and metacarpus measurements were calculated on a pooled within breed cross basis, they were generally considerably lower than on an overall breed cross basis. On more uniform populations such as within a breed type, differences in bone size were less accurately evaluated.

c. Current Status and Research Plans:

No major efforts will be made to develop instruments and procedures for determining composition in the live animal, but as promising procedures are developed they will be evaluated for their potential use for research and industry.

2. Research Area:

Production Factors that Influence Carcass Composition and Meat Quality

a. Objectives:

- (1) Determine the effects of different nutritional, environmental and management systems on steers which vary greatly in their rate, economy and composition of growth.
- (2) Incorporation of above results into management systems designed to match economical and efficient resource utilization with "growth impulse" for different biological types of cattle.
- (3) Characterization of biological types of cattle represented in GPE program for carcass merit.

b. Research Accomplishments:

Results are given under Nutrition.

c. Current Status and Research Plans:

- (1) Experiments described under Nutrition Item 2.b. include major inputs from the Carcass and Meats area.

3. Research Area:

Develop Information Necessary for Improving Grade Standards for Carcass Beef

a. Objectives:

- (1) Collect data on carcass traits indicative of qualitative and quantitative characteristics in a wide range of biological types of cattle.
- (2) Assessment of qualitative characteristics in relation to taste panel acceptance scores.

b. Research Accomplishments or Progress:

- (1) Analysis of quality-palatability data from the carcasses of 496 steers obtained by mating seven sire breeds to two dam breeds has been completed. Marbling scores of traces⁺ are sufficient to ensure a desirable rating in taste panel score when maturity is A- to A^o. In this maturity range, marbling score and USDA quality grade accounted for 9 and 11%, respectively, of the variation in taste panel acceptability. A 230% variation (3 to 7%) in ether extract of the longissimus dorsi muscle had no effect on taste panel acceptability. Length of feeding period had no effect on components of palatability or overall acceptability.
- (2) This study assessed the value of certain USDA quality grade factors as predictors of cooked meat palatability. The 496 steer carcasses evaluated were from cattle differing widely in growth characteristics and therefore in body composition at time of slaughter. The components of quality grade (conformation, maturity, marbling, color, firmness and texture of lean) accounted for no more than 10% of the variation in taste panel traits (tenderness, flavor, juiciness and overall acceptability). Eating quality of rib steaks from carcasses of A maturity was acceptable when the longissimus muscle contained as little as 2.9% chemical fat. This approximates the marbling level required for the lower portion of the USDA Good grade. Increased time on feed (212 to 279 days postweaning) was associated with increased external fat thickness and intramuscular fat content ($P<0.01$) but had no influence on taste panel traits ($P>0.05$).
- (3) The purpose of one experiment was to assess the predictive value of Armour tenderometer (AT) measurements for certain carcass and organoleptic traits for beef carcasses that varied greatly in body composition. Marbling score alone accounted for 10% of the variation in taste panel tenderness.

The additional variation accounted for by the AT measurement in a multiple regression equation ($R^2= 0.14$) is of questionable practical importance even though the usefulness of the AT was increased when used at constant marbling score or in conjunction with marbling.

(4) Carcasses of 786 steers derived from crosses of Hereford or Angus cows bred to Hereford, Angus, Charolais, Limousin, Simmental, South Devon and Jersey sires were fabricated into closely trimmed, semiboneless retail cuts to study relationships among independent variables in the USDA yield grade equation in breed groups that differ in growth and fattening characteristics.

Simple correlations indicate carcass weight was a good predictor of cutability within a breed group but a poor indicator over all breed groups.

Longissimus muscle area had the lowest predictive value of the four variables studied. It may be more useful in populations of similar weight than in those varying widely in weight. Fat thickness at the 12th rib was the most useful predictor of cutability and is about equally useful within or over all breed groups. Percentage of kidney and pelvic fat, though lower in predictive value than 12th rib fat thickness, was useful within or over breed groups. Partial regression coefficients computed within each breed group were relatively similar though there were significant differences in intercept values for the different breed groups. Use of a single prediction equation for all breed groups would rank animals well within a breed group but would on the average underestimate or overestimate animals of a breed group by .1% to over 1% relative to actual cutability.

c. Current Status:

- (1) Further analysis of the above data is planned with retail product (percent and lbs.) as the end point.
- (2) Similar data are currently being collected on other sire breeds mated to the same dam breeds.

d. Research Plans:

- (1) Continued efforts will be made to identify and assess those traits that most accurately reflect the quantitative and qualitative characteristics of carcass beef from steers that differ widely in

biological type and that were raised under different nutritional and management systems.

- (2) Efforts in this area will be collaborative with other appropriate federal agencies and ARS groups.

4. Research Area:

Develop Procedures for Improving Beef Processing and Distribution Efficiency

a. Objectives:

- (1) Development of technology to maximize tenderness by postmortem treatment.
- (2) Development of technology for improvement of sanitary handling procedures for the carcass.
- (3) Evaluation of processing systems for producing uniform fresh meat cuts.

b. Current Status and Research Plans:

- (1) This research area is in the planning stage with implementation of efforts to begin when Phase II facility development and staffing permit.

V. LIVESTOCK ENGINEERING

A. General Objective. In collaboration with scientists from other disciplines, develop a comprehensive program to manage cattle waste from both housed and outdoor feedlots to maximize the value of the waste and minimize the pollution hazard. Develop a comprehensive research program to determine the effects of different factors of the climatic and physical environment on animal performance.

B. Specific Programs.

1. Research Area:

Management of Runoff from Outdoor Feedlots

a. Objectives:

- (1) To evaluate over several years a system for managing runoff from a large feedlot.

b. Procedure and Accomplishments:

- (1) A runoff control system for a 6,000 animal

capacity beef feedlot at the U. S. Meat Animal Research Center was designed and put into operation in November 1971. Ditches were constructed below and outside cattle pens to collect and transport runoff to a debris (settling) basin, then to a holding pond. Four systems of reducing runoff velocity (settling solids) were compared in each of the ditches. Effluent samplers and flumes were installed in each of the four ditches to allow measurement of quantity and quality of feedlot runoff. This system was considered to provide excellent runoff control for a large feedlot, but close management is required for successful operation (frequent emptying of holding pond, cleaning ditches and debris basin during one of a few available drying intervals). Data were obtained that will lead to better designs and management of such systems and their components. These data indicate the amount of solids that will be removed from a large feedlot by runoff (that must be collected and stored in properly designed debris basins and ditch systems), the amount of runoff to be expected (and thus stored or utilized) relative to rainfall, and the influence of ditch designs on effectiveness of solids settling. It was determined that effluent can be successfully transported in long lengths of plastic tile where effluent storage may need to be some distance from the point of origin. Data were obtained on the pollutional characteristics of feedlot waste both as runoff and as seepage below the feedlot. Management and component refinements were made during FY 1973, based on data obtained, that should increase the efficiency and lower the initial and operating costs of such systems. The system was modified in 1973 to study a simplified and low-cost outflow system between the debris basin and holding pond. Instrumentation was added to determine the flow rate between the two ponds (detention time). Three samplers and flumes have been relocated to provide greater reliability in measurement of runoff quantity and quality from these areas. Runoff quantity and quality, solids deposition and solids removal from the lots will be studied intensively.

Of 42 rains, 14 produced runoff, and from these 46.7% ran off the lots (runoff was 27.8% of total rainfall). The runoff (R) relation to precipitation (P) was $R = 0.485P - 0.107$ with a correlation coefficient of 0.901. Of the total runoff collected

(223 Ac-in.), 11.9% was lost by evaporation, 13.3% by seepage, and 74.8% was pumped (available for crop use). Total solids removed by runoff was 5.6 ton/acre (DM) or 0.685 tons/acre-in. of runoff. Of these, 40.5% were volatile solids. Solids collected in four ditches below the lots ranged from 3.6 to 19.2% of total solids collected depending on method of reducing velocity flow of runoff. After one year 1,226 yd³ (WB) of solids were collected in four ditches (38%) and the debris basin (62%). Twelve dry days are required to dry solids in ditches and debris basin for removal. There were only 6 such periods during the season, limiting the opportunities for cleaning. Chemical analyses of runoff effluent and soil cores beneath the lots have not been completed.

c. Current Status and Research Plans:

- (1) Runoff composition and quantity and the effectiveness of the present system are continuously monitored.
- (2) This study will be continued and will provide data necessary for development of effective methods to manage feedlot runoff.
- (3) This project has been integrated with a project on land disposal of effluent from feedlot runoff.

2. Research Area:

Land Disposal of Effluent from Feedlot Runoff

a. Objectives:

- (1) Determine the cumulative chemical and physical effects upon the soil and crop production from the substitution of runoff effluent for irrigation water and plant nutrients in meeting the irrigation and nutrient requirements of corn.
- (2) Study the cumulative effects upon the soil and crops from frequent applications of runoff effluent as irrigation in excess of the water requirement of the crop in seasons of high runoff from precipitation.
- (3) Establish recommendations for the management of effluent disposal systems to optimize utilization of water and nutrients (N and P) commensurate with required investment and labor.

b. Procedure and Progress:

- (1) A project involving U. S. Meat Animal Research Center and University of Nebraska scientists and scientists in the ARS Soil, Water and Animal Waste Management Research Unit, Lincoln, was initiated in 1973. Variables under investigation were production of forage and grain; quality of forage and grain produced; number of applications and amount of effluent applied as irrigation; nutrients applied in effluent; soil structure (bulk density, hydraulic conductivity of disturbed cores, pore size distribution, wet and dry aggregate analysis); chemical content of soil profile and soil surface; nutrient balance (applied, removed by crop, stored in soil); and crop nutrients required through fertilizers.

All plots are uniformly tilled, planted and harvested. The treatments applied vary only in the application of irrigation water, effluent and fertilizer. Treatments were:

- (a) Control--irrigate with water to meet irrigation requirements of corn.
- (b) Effluent--irrigate with effluent to meet irrigation requirement as on control treatment. This may require supplementing or replacing the effluent with water during periods without runoff.
- (c) Irrigate with effluent to maximize disposal by exceeding the water requirement of the crop when effluent is available for distribution. In years when effluent is not available, irrigation with water to meet the requirement of the crop will be practiced as in Treatment (a). Rainfall plus irrigation will be in the range of 50 to 60 inches for a crop year in years with well distributed runoff events.

Comparisons of the various effects of the treatments will be made on the basis of periodic soil chemical and physical analyses, and quality and yield of grain and forage. Measures of these parameters will be obtained from the various samples taken and techniques employed and from comparisons of paired samples. Data from the plots irrigated with water (Control) will be used as a basis for comparing the treatments. Tabular and graphical comparisons will be made of the data obtained.

c. Current Status and Research Plans:

(1) This project is in progress and will continue for several (5 to 10) years. It will be expanded and modified as new information becomes available.

3. Research Area:

Cattle Waste from Confinement Production Systems

a. Objectives:

(1) To evaluate systems for managing waste in confinement production systems.

(2) To develop systems to most effectively dispose of and utilize animal waste in confinement production systems.

b. Progress and Current Status:

(1) Several systems for managing waste are being designed for the intensive cattle facilities to evaluate different systems for managing waste. These include: an automated drag system to provide dry waste, a flume flushing system, an open flushing gutter system and a concrete slab.

c. Research Plans:

(1) A comprehensive project will be developed in collaboration with the ARS Soil, Water and Animal Waste Management Research Unit, Lincoln, and with State Agricultural Experiment Station staff.

(2) This will be a continuous long-term program directed toward developing technology for removal and utilization of animal waste in a beef confinement system.

4. Research Area:

Climatic and Physical Variables on Animal Performance

a. Objectives:

(1) To determine the effects of weather variables on animal performance, including climatic-breed interactions.

- (2) To evaluate the need for summer and winter protection of feedlot animals.
- (3) To evaluate factors such as animal density and feed bunk space on animal performance.
- (4) To evaluate shelter requirements for cattle during different phases of the life cycle, including early weaned calves, cows during parturition, etc.

b. Procedure and Accomplishments:

- (1) A three-year study, involving 1,123 steers representing a wide range in biological types, was conducted to evaluate weather-breed interactions and to examine the influence of certain weather variables on postweaning gain and feed efficiency in feedlot cattle. No significant interactions were found between weather variables (maximum, minimum and mean temperature, rainfall and wind velocity) and biological type.

Although direct effects of rainfall and mud resulting from rainfall could not be separated, it appears that mud was the primary factor affecting gain and feed efficiency. One inch increase in rainfall during the winter increased TDN intake/animal/day by 2.577 lb (1.171 kg), decreased ADG by 0.261 lb (0.119 kg) and increased TDN/gain by 1.117. The standard partial regression coefficients reveal that in the winter, rainfall was twice as important as average minimum air temperature ($0.534 \div 0.256$) and 6.3 times more important than average maximum air temperature in affecting TDN/gain while in the summer average minimum air temperature was relatively more important. In the summer, average minimum air temperature was 25 times more important than rainfall and 215 times more important than average maximum air temperature in influencing ADG. In the summer, each 1 °F (0.5 °C) increase in minimum air temperature resulted in a decrease of 0.061 lb (0.028 kg) ADG.

- (2) The influence of windbreaks on winter production of beef cattle was investigated at the U. S. Meat Animal Research Center during the winters of 1971, 1972 and 1973. Six pens 50' x 212' (15 m x 61 m) were used each year with 33 to 42 heifers per pen. Two pens each year had no windbreaks; four pens had windbreaks 200 ft (61 m)

from the feedbunks in 1971. Two windbreaks were moved to within 70 ft (21 m) of the feedbunks in the 1972 and 1973 tests. The windbreaks were 70 ft (21 m) long and 10 ft (3 m) high with 78% solid areas.

The only significant difference in daily gain among treatments in the two years was a gain of 0.04 kg/day less per animal in the far windbreak pens compared with the cattle with no windbreaks in 1972.

Feed intake was significantly less for cattle with windbreaks than for those with no windbreaks in Experiment 1971, and cattle with horizontal-board windbreaks consumed less feed than those with vertical-board windbreaks. There were no differences in feed intake due to treatment in 1972 and 1973. Activity observation indicated the cattle with far windbreaks (200 ft from feedbunks) were at the feedbunks about 4% less each day between 0800 and 1600 hours than cattle with no windbreaks or those with close windbreaks. Gain of cattle with close windbreaks (70 ft) tended to be better than for cattle with the far windbreaks, but less than for cattle with no windbreaks.

Windbreaks reduced the average air velocity only about 3 mph behind the windbreaks where cattle spent about one-half their time. This small wind reduction reduced any potential advantage of windbreaks.

- (3) Two year's data indicate that summer shade and winter shelter do not significantly influence postweaning performance of beef cattle in this area. Area provided for shade and shelter was 25 ft²/animal. The study involved four pens and approximately 100 animals per season for a total of 400 animals.

c. Current Status:

- (1) No studies are in progress at this time.

d. Research Plans:

- (1) A comprehensive program will be developed in this area and will be integrated with several other disciplines.

5. Research Area:

Methods to Minimize Mud Problems in Cattle Feedlots

a. Objectives:

- (1) To study soil treatments designed to decrease wetability and swelling and increase the mechanical stability and bearing stress of the feedlot soil surface.
- (2) To study treatments and practices to reduce mixing of organic materials with soil on the feedlot surface.
- (3) Identify treatments and management practices to optimize feedlot drainage and eliminate development of mud in high animal traffic areas.

b. Procedure and Current Status:

The first of a series of studies was initiated in 1974. Treatments were as follows:

- (1) Control--continue previous management; mounds in pens are reworked each year and the lot surfaces resmoothed and compacted.
- (2) Stabilize selected area (high animal traffic) adjacent to concrete aprons along feedbunks and waterer. The soil on the selected area will be stabilized with hydrated lime and compacted to a depth of 12 inches. The remaining area of the pen will be managed as the control pen.
- (3) Stabilize selected area (high animal traffic) adjacent to concrete aprons along feedbunks and waterer. The soil on the selected area will be stabilized and compacted to a depth of 6 inches. The remaining area of the pen will be managed as the control pen.

Stabilization will be accomplished by thorough mixing of 4 to 6% (by weight) hydrated lime into the soil, wetting, compacting and curing for one week. The 6-inch depth of stabilization will be accomplished in a single sequence. The 12-inch depth of stabilization will require two sequences--one for the initial and one for the upper 6-inch depth--of mixing, wetting and compacting. Curing between sequences will not be required.

Six pens of identical dimensions and without apparent differences in physical aspects will be used in the study. The animals stocked in these pens will be included in research not otherwise related to this study. The six pens will provide two complete blocks of pens--each block having an untreated control pen and pens with each of the two depths of treated soil.

c. Research Plans:

- (1) Other studies will be developed in this area.

VI. HERD HEALTH AND DISEASE MANAGEMENT

A. General Objective. In collaboration with the National Animal Disease Center and with other research programs oriented toward the protection of cattle from the hazards of diseases and parasites and with other Research Units at the U. S. Meat Animal Research Center, develop a program to "bridge the gap" between production and protection research objectives to provide for a more comprehensive beef cattle research program.

B. Specific Programs.

1. Research Area:

Prevention and control of herd health and disease problems that decrease efficiency of cattle production.

a. Objectives:

- (1) Develop management and herd health procedures to reduce stress at weaning and during the early phase of the postweaning growth period.
- (2) Determine the effect of internal and external parasites on production efficiency and evaluate the economic benefit of prevention and treatment.
- (3) Determine the efficacy of an autogenous *M. bovis* bacterin and management regimes for the prevention of "pinkeye".
- (4) Determine nutritional implications in the prevention of enteric and metabolic problems.

b. Procedure and Accomplishments:

- (1) Diagnostic capabilities to monitor herd health are being developed.
- (2) Herd health management procedures for disease prevention have been implemented.

- (3) A study to evaluate the efficacy of an autogenous *M. bovis* bacterin developed by National Animal Disease Center staff for the prevention of pinkeye was evaluated in 240 cow/calf pairs in 1974. A second experiment was conducted in 1975. This work was in cooperation with the National Animal Disease Center.
- (4) Determine the influence of the microbial populations and general herd health status on reproductive performance of the male and female.

c. Current Status and Research Plans:

- (1) Herd health management program and herd health diagnostic capabilities will continuously be revised and developed.
- (2) Results to date indicate that the *M. bovis* bacterin is not effective in preventing pinkeye under field conditions.
- (3) Other collaborative studies will be developed with National Animal Disease Center and other cooperating ARS Research Units and State Agricultural Experiment Stations. In order for the U. S. Meat Animal Research Center to "bridge the gap" between production and disease research, it is necessary to have a diagnostic and research capability on site. It is planned to add a Herd Health and Disease Management Research Unit involving 4-5 scientists.

VII. MANAGEMENT SYSTEMS

A. General Objective. Develop production systems which maximize resource conversion rate to beef most appropriate for market requirements through the optimum synchronization of all available beef production resources. Identify knowledge voids and determine the relevance of filling these voids to provide a basis for more effective research planning in regard to research resource use.

B. Specific Programs.

1. Research Area:

Model Simulation

a. Objectives:

- (1) Develop and experimentally evaluate component biological models of herd dynamics, nutrition, reproduction and product yield as a basis for the development of optimum production "equations".

(2) Identify information deficiencies and establish priorities of research needs.

b. Current Status:

Collaborative efforts with the Texas Agricultural Experiment Station have made available some of the necessary component models. The agreement provides for joint efforts in the continued development and refinement of these and additional models. The U. S. Meat Animal Research Center is currently working to validate and refine these component models. Efforts to generalize the models to accommodate more than one genotype are being initiated.

c. Research Plans:

Major emphasis will be given to the development of beef cattle simulation models with work in this area furnishing the experience necessary for similar efforts in sheep and swine. The experimental evaluation of component biological models will be fully integrated with research in other appropriate disciplines.

2. Research Area:

Production Systems

a. Objectives:

- (1) Develop efficient beef production strategies for various market requirement and resource "sets".
- (2) Validate the more promising of these production systems.

b. Current Status:

Data relevant to the evaluation of beef production systems is being collected and synthesized from all ongoing U. S. Meat Animal Research Center research and from the literature. Development of simulation models (1. above) has been initiated. In addition, ad hoc modeling techniques are being employed to provide synthesis and economic interpretation of experimental results. These efforts currently include the assessment of calving difficulty, efficiency of postweaning growth and carcass merit of cattle produced in the first cycle of the Germ Plasm Evaluation Program. Experiments with major management systems emphasis will be conducted as appropriate. One of these related to high forage feeding regimes for growing-finishing

steers was completed this winter. Two types of steers (small, early maturing vs. large, late maturing) were fed on five feeding regimes utilizing large quantities of roughages. The major objective of this experiment is to establish the minimum amount and correct timing of concentrates necessary to produce beef or acceptable palatability.

c. Research Plans:

Major research efforts are planned in beef production systems research. A number of production alternatives to be evaluated at an early date include: breeding programs (rotational crossing, synthetics, specific crosses, etc.); use of AI programs; length of breeding season; criteria for culling; feeding regimes for growing-finishing cattle; methods of reducing calving difficulty; and desirable biological type in terms of mature size, milk level and maturing pattern.

The validation of complete beef production systems will likely necessitate collaborative efforts with other research organizations and private interests. It is anticipated that consulting/data feedback arrangements with a few well-managed, private enterprises will be essential in developing the full potential of the modeling tool.

U. S. MEAT ANIMAL RESEARCH CENTER
PUBLICATIONS - BEEF CATTLE

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